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Description

- 5 Method for operating an image system of an imaging medical examination device and medical examination device

10 The invention relates to a method for operating an image system of an imaging medical examination device, the image system having a reception unit for receiving a plurality of signals arising at different locations, and a display unit for the imaging representation of pixels, the pixels each being  
15 assigned at least one signal. The invention additionally relates to an imaging medical examination device having an image system, the image system having a reception unit for receiving a plurality of signals arising at different locations,  
20 and a display unit for the imaging representation of pixels, the pixels each being assigned at least one signal.

In medical X-ray technology use is made of digital  
25 imaging systems having a reception unit with a digital image converter - instead of an analog image converter. Such a digital image converter acquires an image comprising a plurality of pixels. An individual pixel can be generated e.g. by the signal of an  
30 individual element of a photodiode array, of a CCD image converter or an amorphous silicon detector (a:Si detector). The individual elements receive light signals arising at different locations and image them on a display unit in an imaging fashion.

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Image converters of this type can be affected by pixel failures caused e.g. by the failure of an individual converter element. There may also be pixel

failures in groups (so-called clusters), which lead to the failure of entire lines or columns and are caused for example by interruptions in the address lines.

5 The failure of one or more pixels or measurement channels can lead to image artifacts of greater or lesser severity, which become visible for example as black rings in a computer tomograph image. If every image converter affected by such an artifact were  
10 discarded from the series during the production of a digital image system, this would lead to a high reject rate. On the other hand, however, given the multiplicity of pixels present, it is not necessary for the signal of every individual measurement  
15 channel to reach the imaging stage. In order to decrease the rejection of detectors, it is known, therefore, for example from DE 195 27 179 C1 or from DE 195 27 148 C1, to correct a defective pixel. For this purpose, the procedure is performed in two  
20 steps: firstly a defect determination takes place, which yields information about which pixels are defective and which are good. When this information is present, the defective pixels can be corrected in a second step. The correction can be achieved for  
25 example by replacing the defective pixels by linear interpolation of adjacent pixels. For the correction of column or line defects, DE 195 27 179 C1 discloses proceeding separately according to line defects in a first correction step and according to column defects  
30 in a second correction step.

A correction circuit - based on an interpolation method - for correcting defective pixels in an image system or a CCD apparatus is also disclosed in EP 0  
35 687 106 A1.

Proceeding from an image system with a potentially defective pixel, the invention is based on the object

of specifying a method for operating such an image system in an imaging medical examination device which improves the reliability of the operation of the image system. An imaging medical examination device  
5 having an image system is also intended to be specified for the same purpose.

The first-mentioned object is achieved, relative to a method of the type mentioned in the introduction, by virtue of the fact that an event of the undisturbed  
10 operation of the medical examination device automatically triggers a defect determination for determining a defective pixel possibly present in the image.

15 The defect determination can be performed as it were on line during use and not just once after the production of the digital image sensor or during the calibration thereof. This makes it possible firstly for imminent defects already to be identified at a  
20 point in time at which the image is not yet severely disturbed. Secondly, it is thus possible to effect continuous correction of newly occurring defects, so that even over a long period of operation, the quality of the images recorded by the image sensor  
25 having an increasing number of defects is not impaired or is virtually unimpaired.

In particular, an event that occurs anyway during operation is used or a triggering event is generated  
30 during the undisturbed operation.

In this case, the invention is based on the insight that in image systems of future medical examination devices, defective pixels will have to be reckoned  
35 with to an increasing extent, since the number of detector channels will rise. It will increasingly happen that such image or channel failures will not occur until during clinical operation and interrupt

the latter or at least cause massive disruption thereto. Although occasionally the defects may arise as early as during the production of the digital image converter, there is nonetheless the risk that

5 further defects or indeed the first manifestation of defects will occur during the use and operation of the digital image converter, that is to say e.g. during clinical use, and interrupt the latter or at least cause massive disruption thereto. In the case

10 of the method according to the invention, such defects and, consequently, an operational disruption are counteracted since the defect determination is triggered automatically. This means that it is possible, in particular, for an imminent defect

15 already to be detected at a point in time at which the image is not yet severely disturbed, in order to initiate suitable countermeasures before the occurrence of a later severe disturbance. The method additionally has the advantage that separate

20 intervention by an operator is not necessary to trigger the defect determination. Rather, the defect determination can take place without the action and even without the knowledge of an operator.

25 According to a preferred embodiment, the triggering event is derived from an operating process which does not serve for the defect determination, in particular from an operator's control process which does not serve for the defect determination.

30 Preferably, the triggering event is derived from a switch-on process performed on the medical examination device. By way of example, a defect determination sequence or a defect determination

35 algorithm is automatically triggered when the medical examination device is switched on.

It is likewise preferred for the triggering event to

be derived from a calibration process performed on the medical examination device. Such a calibration process is carried out e.g. when the examination device is switched on or during the operation of said examination device by an operator, e.g. by a doctor. During this calibration process, the image channels or pixels are calibrated individually and immediately examined with regard to a defect during this opportunity.

Preferably, the triggering event is generated at a defined point in time before, during or after an image acquisition procedure, in particular before, during or after a patient examination or a scan.

The triggering event can also be generated by a counting process. In particular, the counting process counts a process which is repeated during operation of the medical examination device, in particular a switch-on process, a calibration process and/or examination process. A trigger signal as the triggering event is triggered for example whenever the counting process has continued counting by a constant interval. This affords the advantage that a defect determination is automatically triggered whenever the image system has been exposed to a high load and, accordingly, it is with increased probability that the occurrence of defects is to be reckoned with.

It is likewise preferred for the triggering event to be generated by a time measuring process. For this purpose, a corresponding trigger signal can be derived for example from a clock generator or a timer of a computer which controls the examination device. By way of example, a trigger signal or trigger event is generated at fixed time intervals, for example hourly.

According to an especially preferred refinement, after the defect determination, a correction process is automatically triggered if a defective pixel was detected. As a result, outage times of the

5 examination device in clinical operation are avoided to the greatest possible extent. Image artifacts become visible only to a very small extent or only sporadically.

Preferably, during the correction process, the  
10 assignment of the defective pixel to its signal is canceled and, instead of this, the pixel is assigned one or more signals of one or more other pixels. By way of example, interpolation from the signals of adjacent pixels takes place.

15 The above-described correction process by newly assigning one or more signals of one or more other pixels to a defective pixel leads to complete elimination of an image artifact. Such a correction  
20 process is carried out as sole correction measure in particular in the edge area of a computer tomograph image, since, in the edge area, the failure of the information from a single pixel does not lead to significant impairment of the meaningfulness of the  
25 image.

The automatic performance of a correction process has the advantage that the service costs for the examination device are significantly reduced since  
30 the attendance of service personnel will in many cases not be necessary.

The correction process is, in particular, an interpolation process in which interpolation is effected,  
35 for example linearly, between pixels adjacent to a defective pixel. By way of example, the correction process according to the patent claims of DE 195 27 179 C1 is employed. It is also possible to use the

correction measures described in EP 0 687 106 A1, in particular as set forth therein in the claims.

The defect determination takes place, in particular,  
5 according to a method as disclosed in the patent claims of DE 195 27 148 C1.

The medical examination device is, for example, a computer tomograph, a magnetic resonance imaging  
10 scanner or a conventional X-ray apparatus, e.g. a radiography apparatus.

In one specific embodiment of the method, it is provided that in connection with the defect  
15 determination after carrying out a first correction process in which already known image defects are corrected, the corrected image is analyzed in order to determine further defects or defects that are still present, which are corrected in a second  
20 correction process. Thus, a two-stage correction takes place.

In the specific embodiment mentioned, the method according to the invention advantageously provides a  
25 two-stage correction of an image currently being recorded, or of a chronologically previously recorded image loaded from a memory. First of all, in a first correction process, a first correction of the image or of the image signals is effected in order to  
30 correct already known defects which were determined e.g. as early as after the production of the reception unit in the context of serviceability tests. After this correction process, an image is present which has been corrected for the first time  
35 and is already largely free of defects on account of the correction. In order then to identify new defects, the already corrected image is subsequently analyzed. Depending on whether or not further defects

are then identified, the image is either corrected in a second correction process in order to eliminate the new defects, if such have been detected. If no further defects are present, then the image can be  
5 processed further and output.

What is effected here, then, is firstly a correction of the defects known as it were "off line" and, in addition, a correction of the defects ascertained "on  
10 line", on account of the defect analysis, performed according to the invention, of the image currently being recorded. The correction is thus effected with regard to the defects that are actually present in the image, and not just with regard to the already  
15 known defects that were indeed determined earlier and, if appropriate, may only constitute a portion of the overall defects.

The image itself can be filtered after the first  
20 correction process, after which the filtered image is first analyzed, in which case e.g. a median filter or a high-pass filter can be used as the filter. The defect-free image areas are filtered out in the context of this filtering, with the result that only  
25 image areas that are possibly still affected by defects are visible in the filtered image on which the analysis is based.

According to the invention, in the context of the  
30 analysis, the pixel-related signals may then be compared with one or more threshold values. A defect may be identified in the context of this analysis e.g. from the fact that the signal falls below a threshold value or, alternatively, that the signal or  
35 the signal noise exceeds or falls below a specific threshold value. A defect can also be identified using already filtered signals in the manner described. In a development of the invention, this



analysis result may then be used to generate a new defect map, which describes the detected defect or defects that is or are new or still present, and which is used to effect the correction in the second  
5 correction process. In this case - like the first correction previously - the correction can be effected by means of any known correction method, e.g. by means of the correction methods already described in the documents DE 195 27 179 C1 or DE 195  
10 27 148 C1 mentioned in the introduction.

In this case, in the context of the first correction process, the image may be corrected using an old defect map, which describes already known defects.  
15 This old defect map is used as a basis for the first correction process; it specifies the position of the already known defects, as were determined e.g. after the production of the reception unit or in the course of earlier calibration, thereby enabling a targeted  
20 defect correction in the context of the first correction process.

Since the newly detected defects are normally permanent defects which would likewise occur again in  
25 subsequently recorded images, it has proved to be particularly expedient if the old defect map is updated using the new defect map. In other words, the newly determined defects are concurrently included in the old defect map, and the latter is thus adapted to  
30 the given defect situation and updated, with the result that, in the context of the first correction process of a subsequently recorded image, both the new defects already known at the time and the new defects determined in the last detection and  
35 correction step are immediately corrected. The old defect map is thus continuously adapted to the actual defect state.

In this case, the updating can be effected only when one or more defects that are newly present or still present are detected. This advantageously avoids the situation in which a step of updating the old defect  
5 map takes place after each new defect determination even when no new defects have been determined.

Finally, it may be provided that a flat-fielding correction of the image is effected in the context of  
10 the first correction process. In the context of this known flat-fielding correction, firstly the recorded image is corrected using an offset image, by means of which the originally provided offset of the digital reception unit is corrected. Furthermore, a  
15 correction is effected using a gain image, which takes account of the different gain factors of the individual pixels. This flat-fielding correction is intrinsically known per se and need not be discussed in any further detail.

Moreover, the method is configured in a particularly preferred manner in that after the defect  
20 determination, a message is automatically sent via a data link to a service device if a defective pixel was detected. This affords the advantage that the  
25 service device is continuously informed about defects that occur on the examination device. It can then decide remotely, for example, whether a correction process that may already have been triggered  
30 automatically suffices to eliminate the defective pixel, or whether further-reaching measures should be initiated, e.g. replacing the reception unit.

When the defect determination is carried out, a pixel  
35 is detected as defective preferably by virtue of the fact that the assigned signal falls below a minimum value and/or the noise in the assigned signal exceeds a maximum value. The determination of the noise, in

particular, enables imminent defects to be identified in good time.

5 The defect determination can also be carried out on a stored image. This is advantageous in particular if the defect determination is triggered by an event at the instant of whose occurrence no image data are regularly present, such as e.g. if a trigger signal is generated at fixed time intervals.

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The apparatus-related object is achieved, relative to the medical examination device mentioned in the introduction, by means of a detection device for automatically determining a defective pixel possibly present in the image, in which case the detection device can be activated by an event of the undisturbed operation of the medical examination device.

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20 Such a medical examination device is particularly suitable for carrying out the method according to the invention. When the detection device is activated, the defect determination can be triggered in said detection device.

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The advantages and configurations mentioned with regard to the method apply analogously to the medical examination device according to the invention.

30 Preferably, the detection device can detect a pixel as defective if the assigned signal falls below a minimum value and/or if the noise in the assigned signal exceeds a maximum value.

35 According to a particularly preferred refinement, the examination device has a correction device for automatically eliminating a defective pixel that has possibly been detected, in which case the correction

device is connected to the detection device and can be activated by the latter if a defective pixel is detected.

5 Such a preferred examination device is distinguished for example by the fact that the detection device is designed for analysis of the image that has been corrected by means of the correction device a first time with regard to already known defects, for the  
10 purpose of determining defects that are new or still present, and the correction device is designed for renewed correction of the corrected image with regard to the defect or defects that is or are new or still present.

15 In this case, the detection device has a filter for filtering the image after the first correction process and an analysis means for determining one or more defects that is or are new or still present, the  
20 filter expediently being a median filter or a high-pass filter.

The analysis means itself may be designed for comparing the pixel-related signals with one or more  
25 threshold values for the purpose of determining a defect. Furthermore, the analysis means or the detection device may be designed for generating a new defect map, which describes the detected defect or defects that is or are new or still present, and the  
30 correction device may be designed for correcting the image in the second correction process using the new defect map. Finally, the correction device may be designed for correcting the image using an old defect map, which describes already known defects, in the  
35 context of the first correction process.

Furthermore, it is expedient if the detection device or the correction device is designed for updating the

old defect map using the new defect map. In this case, the respective defect maps may be stored either in the detection device or the correction device, that device where the defect maps are stored  
5 expediently carrying out the corresponding updating.

Finally, the correction device may be designed for carrying out a flat-fielding correction of the image in the context of the first correction process.

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It is additionally preferred for the detection device to have a data interface for sending a message to a service device, in which case the message can be sent automatically by the detection device if a defective  
15 pixel is detected.

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The detection device may also be connected to an image memory, from which it is possible to retrieve an image which was generated by the image system at  
20 an earlier point in time.

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Exemplary embodiments of an examination device and of a method according to the invention are explained in more detail below with reference to figures 1 to 3,  
25 in which:

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Figure 1 shows a medical examination device according to the invention in a diagrammatic overview,

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Figure 2 shows a flow diagram of a method according to the invention in a first exemplary embodiment, and

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Figure 3 shows a flow diagram of a method according to the invention in a second exemplary embodiment.

**Figure 1** shows a medical examination device designated in its entirety by the reference numeral 1, said device comprising an X-ray tube 3 fed by a high-voltage generator 5. An X-ray beam 7 emitted by the X-ray tube 3 penetrates through a patient 9 and passes to a digital image system 10 of the examination device 1 in accordance with the location-dependent transparency of the patient 9.

The image system 10 has a reception unit 11 composed of a scintillator matrix 13 and a photodiode array 15. In the scintillator matrix 13, wave conversion from invisible X-ray radiation into radiation detectable for semiconductor diodes takes place. Each pixel of the scintillator matrix 13 is assigned an element of the photodiode array 15, with the result that the light signals arising at different locations in accordance with the location-dependent transparency of the patient 9 are converted into electronic signals.

The individual channels of the reception unit 11 are fed to an evaluation unit 17, which, for its part, is connected to a display unit 19, e.g. a screen. In the evaluation unit 17, the signals of the individual image channels are conditioned and converted into a video signal.

The examination device 1 additionally has a detection device 31 for automatically determining a defective pixel possibly present in the image of the display unit 19. The detection device 31 is connected to the evaluation unit 17 via a data line 33 and receives, via said data line 33, information about the signals of the individual pixels or channels.

The detection device 31 can be triggered or activated by different events:

- a) by one or more control processes performed by an operator which are defined in advance and are performed on a control console 35, e.g. by a switch-on process, by a calibration process or by an examination process or an individual image recording (see e.g. reference symbol 75 in figure 3),
- b) by a time-controlled signal from a clock 37,
- c) by a counter-controlled signal from a counter 39 which counts the number of patient examinations performed.

The detection device 31 can be activated by one or more of these trigger processes a) to c). In the case of activation of the detection device 31, the image data that are currently available via the data line 33, or the image data that were stored in an image memory 40 at an earlier point in time, are automatically analyzed with regard to defective pixels. For this purpose, the detection device 31 has an analysis means 42, which is designed e.g. for comparing the individual pixel-related image signals of the image to be analyzed with suitable threshold values.

The detection device 31 is connected to a correction device 41, which, for its part, acts on the evaluation unit 17. In the case where a defective pixel has been determined by the detection device 31, a correction process is automatically initiated in the correction device 41, the defective pixel being eliminated by means of said correction process. By way of example, a correction procedure is implemented in the correction device 41, which correction procedure cancels the assignment of the defective pixel to its previous signal, and, after the

execution of said correction procedure, the pixel is instead assigned one or more signals of one or more adjacent pixels. By way of example, interpolation is effected between adjacent pixels.

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In addition or as an alternative to the triggering of the correction process, a message is automatically generated by the detection device 31 when a defective pixel appears. For this case, the detection device 31 has a data interface 45 from which there leads a data link 47 to a service device 49. The message is sent automatically by the detection device 31.

In addition to or besides an interpolation method, low-pass filtering can also be started by the correction device 41.

In the exemplary embodiment shown, the examination device 1 is designed in such a way that the correction can also be effected in two steps. For this purpose, an old defect map 50 is stored in the detection device 31. Already known defects of the reception unit 11, which lead to image artifacts, are described and defined in said old defect map 50. The correction device 41 is then designed in such a way that, in a first correction step, the raw image data supplied to the correction device 41 by the detection device 31 are corrected a first time by means of or on the basis of the old defect map 50, in order to correct the already known defects prior to the actual analysis of the image with regard to new defects. This correction using the old defect map 50 precedes a flat-fielding correction using an offset image 51 and a gain image 52, which are stored in the correction device 41 in the example shown.

The image corrected in this way in a first correction process is subsequently passed to the detection



device 31, where it is analyzed by the analysis means 42. The analysis means 42 generates a new defect map 53, provided that new defects are detected. Using this new defect map 53, the image data that have already been corrected in the first correction process are then corrected a further time in the correction device 41 for the purpose of eliminating the new defects. After this second correction process has been carried out, the corrected image data are passed from the correction device 41 to the evaluation unit 17 again and can then be displayed; of course, it is also conceivable for the corrected image data to be written to the memory 40, etc. As is furthermore illustrated in figure 1, the old defect map 50 is subsequently updated using the new defect map 53, with the result that, during a subsequent image correction of an image recorded later, the totality of all the defects then known, which is acquired in the preceding processing step, is corrected.

**Figure 2** shows a first example of a flow diagram of a method according to the invention in simplified form. First of all, an event determination 62 takes place. Various event channels a, b and c are evaluated for this purpose. What are involved in this case are events as occur in the undisturbed operation of the examination device 1 and have been enumerated for example in connection with the description of figure 1.

After an event has been determined and identified as such, a defect determination 63 automatically takes place, in other words all the pixels present are checked with regard to their functionality. That is done by checking each channel with regard to a minimum signal strength.

Afterward, a decision 65 is taken in a manner dependent on the result of the defect determination 63. If no defect was determined, the procedure returns (A) to the state of the event determination 5 62 and again waits for an event. If a defect was determined, a correction process 67 ("channel patch") automatically takes place (B) and/or a message 69 is sent (C) to the service device 49. Afterward, in these cases, (B, C), too, the procedure returns to 10 the waiting state of the event determination 62.

The remote service personnel determine whether - for example in the case of a severe image artifact in the center of the image or in the case of a bone soft- 15 part transmission in an unfavorable projection direction during computer tomography - the reception unit should be replaced entirely or modularly.

**Figure 3** shows a flow diagram of a second exemplary 20 embodiment of the method according to the invention, to be precise with correction in two correction steps.

First of all, calibration ensues in a step 74. Said 25 calibration is carried out e.g. at predetermined time intervals, e.g. every three months or every six months. In the context of this calibration, firstly an old defect map 50, already described with regard to figure 1, is determined by means of known defect 30 determination methods. This old defect map 50 determines the position of detected defects in a recorded calibration image. In the example shown, a line defect, a column defect and also two cluster defects are illustrated by way of example.

35 Furthermore, an offset image 51 and also a gain image 52 are determined in the context of the calibration. These correction means, namely the old defect map 50,

the offset image 51 and the gain image 52, are stored in the detection device 31 and the correction device 41, respectively.

- 5 If an image recording 75 is then effected at an arbitrary point in time, first of all a flat-fielding correction is carried out in step 76. In the context of said flat-fielding correction, the raw image data obtained in the image recording 75 are corrected
- 10 using the offset image 51 and the gain image 52. An old defect map correction is subsequently effected using the old defect map 50 in step 77.

- 15 The image that has been corrected in this way in the first correction process is then filtered in step 78 e.g. by means of a median or high-pass filter, after which the filtered image, by means of step 79, is subjected to an analysis for the purpose of new defect determination by the analysis means 42. If the
- 20 new defect analysis reveals that there are no new defects, the image is immediately output 81 - see the broken line 80. However, if one or more defects or defects that are still present are determined, then a new defect map is created in step 82, using which
- 25 map, in step 83, the correction device 41 then once again corrects the image that was corrected using the old defect map 50 in step 77, in order also to correct these new defects that have now been detected as it were "on line" with respect to the respective
- 30 recorded image. The image that has been doubly corrected in this way (or triply corrected if the flat-fielding correction is considered as a separate correction step) is subsequently output (step 81).

- 35 If a new defect map 53 is generated, then, in step 84, the old defect map 50 is updated using the new defect map 53, with the result that the then corrected or updated old defect map 50 describes the

instantaneous actual defect state. If the then  
updated old defect map 50 is used as a basis, in a  
further process, for the correction of an image that  
is newly recorded later, the totality of defects  
5 known at this point in time are corrected  
automatically.

The evaluation unit 17 and/or the detection device 31  
and/or the correction device 41 and/or the image  
10 memory 40 and/or the control console 35 and/or the  
clock 37 and/or the counter 39 may be designed as a  
component part of a computer system which controls  
the medical examination device 1 and its image system  
10. Correspondingly, the defect determination 63, the  
15 decision 65 and/or the correction process 67 may be  
realized as a computer program for the computer. The  
event determination 62 then runs e.g. continuously in  
the background.

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